

## Better Buildings Residential Network Peer Exchange Call Series:

Making the Most of Home Performance Project Data June 27, 2019



## **Agenda and Ground Rules**

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers:
  - Keith Canfield, CLEAResult
  - Reuven Sussman, American Council for an Energy-Efficient Economy
  - Brian Just, Vermont Energy Investment Corporation
- Open Discussion
- Closing Poll and Announcements

#### **Ground Rules:**

- 1. Sales of services and commercial messages are not appropriate during Peer Exchange Calls.
- 2. Calls are a safe place for discussion; please do not attribute information to individuals on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.





## Better Buildings Residential Network

#### Join the Network

#### **Member Benefits:**

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

#### **Commitment:**

Members only need to provide one number: their organization's number of residential energy upgrades per year, or equivalent.

#### **Upcoming Calls (2<sup>nd</sup> & 4<sup>th</sup> Thursdays):**

- Jul 11: Getting Net Zero Upgrades to Scale The Future is Now
- Jul 17: Bonus Episode! Meet the Winners of the 2019 Home Performance with ENERGY STAR Awards
- Jul 25: Connected Homes and the Grid Flipping the Switch on the Script

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email <a href="mailto:bbresidentialnetwork@ee.doe.gov">bbresidentialnetwork@ee.doe.gov</a>, or go to <a href="mailto:energy.gov/eere/bbrn">energy.gov/eere/bbrn</a> & click Join





## **Opening Poll 1**

- Which best describes your organization's familiarity or experience with home performance data?
  - Very experienced/familiar
  - Some experience/familiarity
  - Limited experience/familiarity
  - No experience/familiarity
  - Not applicable

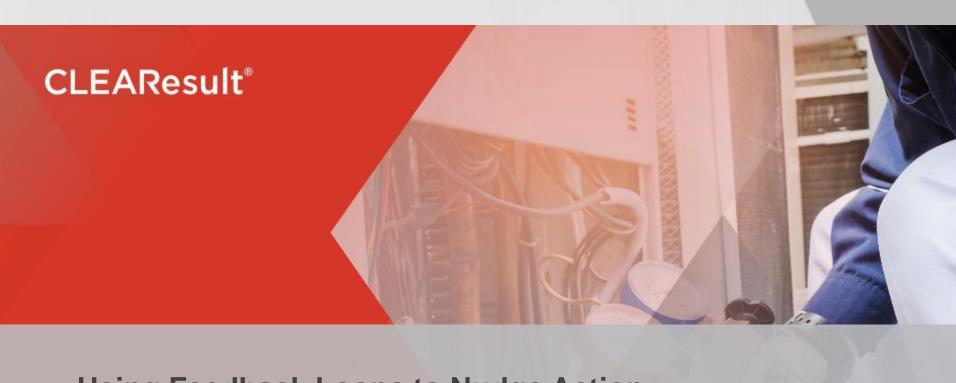






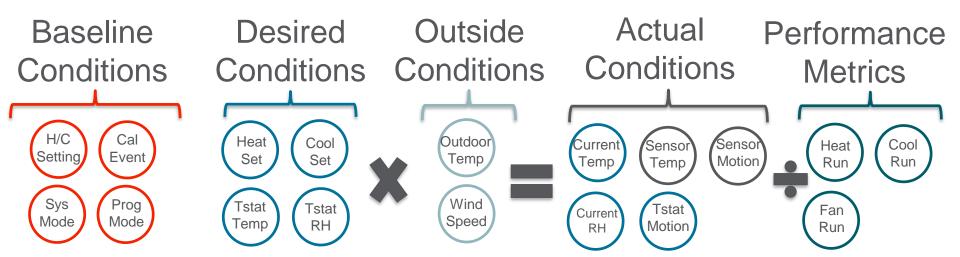
Keith Canfield CLEAResult





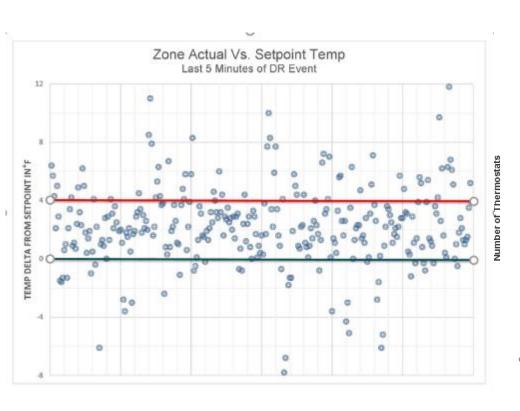
**Using Feedback Loops to Nudge Action** 

#### **Smart Thermostat Data Engine**

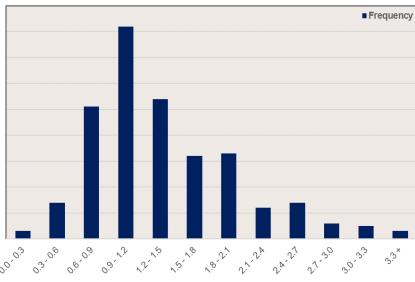


- Smart Thermostat generation of 'high resolution' data
  - 5-minute interval data produces 5,500 datapoints per day, 2 million datapoints per year
- Unlike AMI, thermostat data also represents conditions inside the home
  - Potential to assess envelope and/or system efficiency
  - Allows imputed comfort assumptions

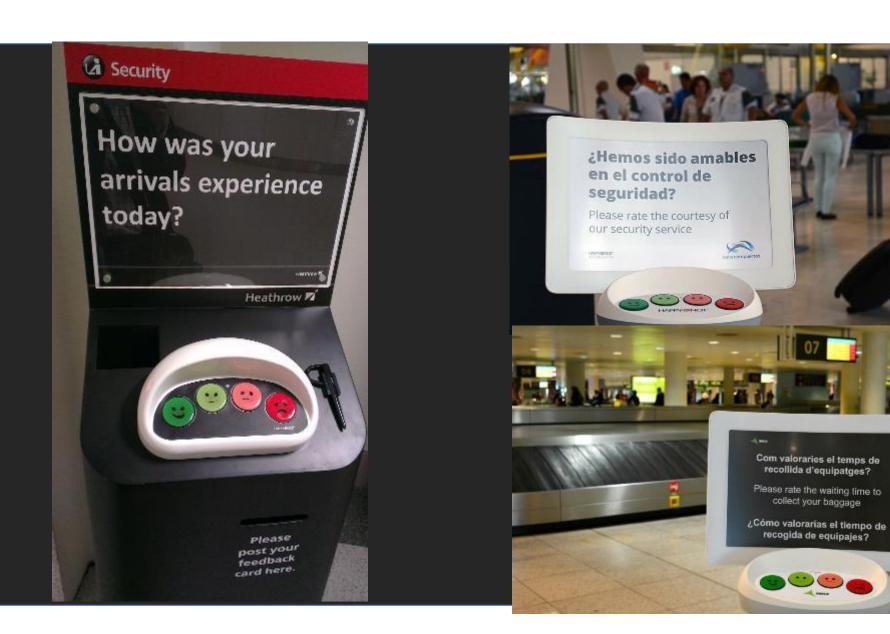
#### What does this look like in the real world?



Heat loss (°F) per Hour at Average Indoor-Outdoor Difference from 12/4/2016 - 2/4/2017

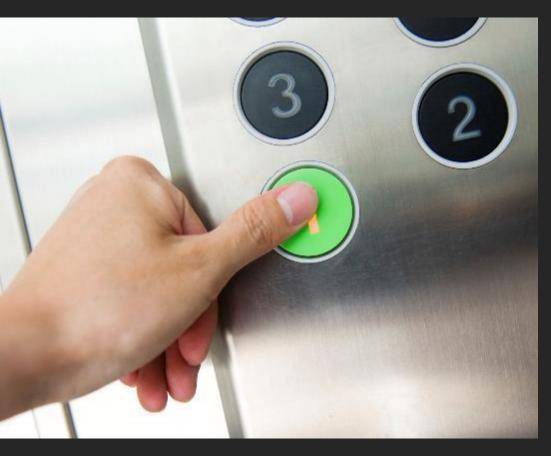


Heat loss per Hour (°F) at Average Difference between Indoor/ Outdoor Temps (36°F)



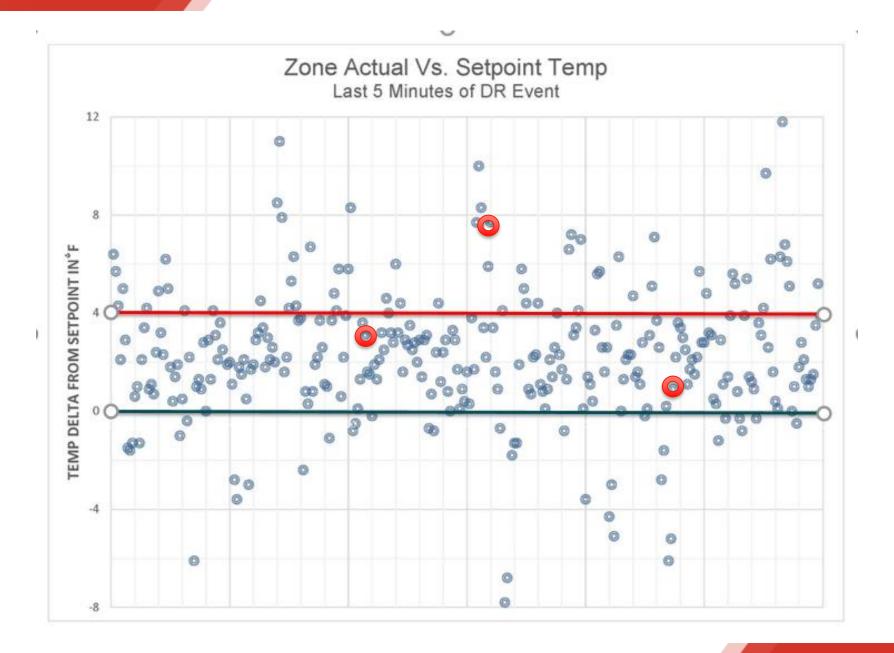






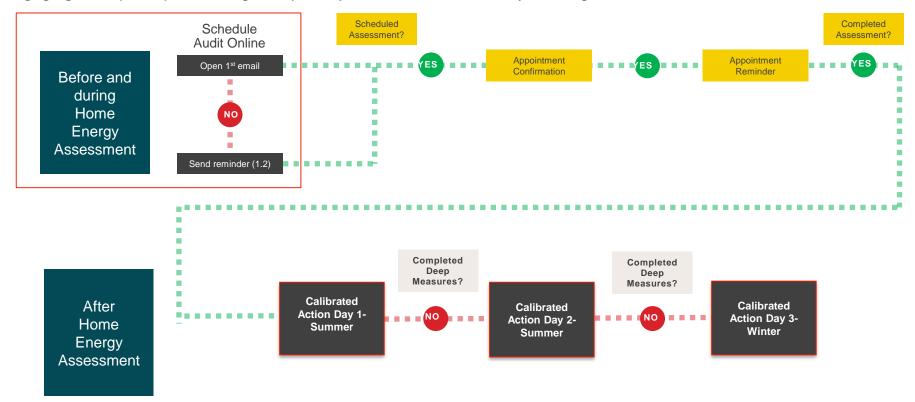






#### **Nudge Opportunities**

Engaging audit participants along their journey with relevant and timely messages



## Thank you. Gracias. Merci. Grazie.

Keith Canfield

keith.canfield@clearesult.com

## **Key Points**

- Smart thermostats can generate high resolution data; a five-minute interval produces 5,500 data points per day.
- Feedback loops from devices such as these can be used to "nudge" homeowner action towards efficiency.
- Such nudge opportunities exist in the engagement of audit participants before, during and after the assessment.







Reuven Sussman

American Council for an Energy-Efficient Economy



## After the Audit: Improving Residential Energy Efficiency Assessment Reports

Dr. Reuven Sussman, Maxine Chikumbo, and Natalia Miller

June 27, 2019: Making the Most of Home Performance Project Data

Report and fact sheet: <a href="http://www.aceee.org/research-report/b1901">http://www.aceee.org/research-report/b1901</a>







Reuven Sussman, Ph.D.

Sr. Manager, Behavior and Human Dimensions Program

American Council for an Energy-Efficient Economy

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Co-Chair of Behavior, Energy and Climate Change conference (BECC)





## What We Did



After the Audit Project Content analysis

Expert review

Eye-tracking study EyeSee

Customer survey

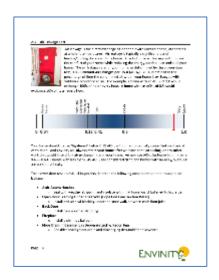


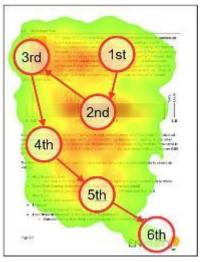
## Eye Tracker



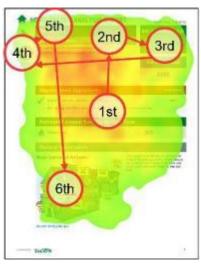
#### Scan Path

- Top and start = most viewed
- Smooth and simple pattern = less skipping











## Six Recommendations



## Six Key Recommendations



- 1. Personalization
- 2. Language
- 3. Behavioral insights
- 4. Design
- 5. Information placement
- 6. Assessment and presentation



#### Personalization

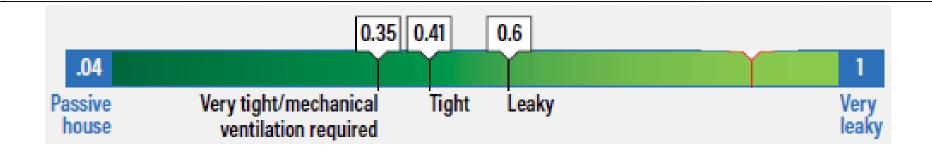


 Custom-tailor content, prioritized recommendations and narrative summary



#### Customization

Thank you for having me in your home and giving HEAT Squad the opportunity to make your home more comfortable and efficient. Your home has an efficient heating system that is thoughtfully managed, and an on-demand hot water heater that is one of the more efficient ways to produce domestic hot water. However, the home does have some significant thermal boundary issues - it's high leakage rate combined with numerous flaws and deficiencies in the thermal boundary are the cause of your high fuel bills. Your home is using more than 85,000 BTU's per square foot of living space. That is almost twice as much as what is considered Energy Star, Englanded, all the emblems anger very fixable - many at gelatively low gost basement (and small origin) area first, with the lowestable being a very close second and the affic space either in percent with





#### Language

Clear and simple



#### Sealing Air Leaks

You'd never leave a window open all year round but that can be the equivalent of the many air leaks around your home including gaps around pipes, windows, recessed lights and electrical outlets. Individual leaks may seem minor, but when taken together hundreds of gaps can create a chimney-like effect that pushes comfortable air up and out of your home, replacing it with air from the outside. Sealing these gaps and cracks keeps the outside air outside and the comfortable air you've paid to heat or cool inside.





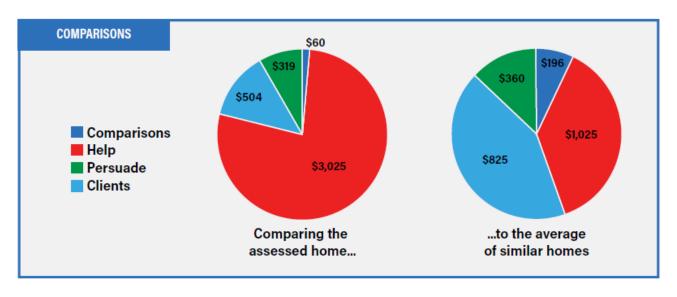
#### Air Sealing

Air infiltrating the home through small cracks and gaps can result in as much as 20% of the typical home's heating and cooling costs. In the winter, cold dry air leaks into the home while the heated air exits. In the summer, the hot outside air enters the home and brings unwanted humidity. Outside air can leak in around window and door frames, floor and ceiling joints, electrical and plumbing access points, wall joints, exhaust fans, etc. While any one of these small leaks may be minor, collectively they can have the same effect as leaving a window open all year long. Air infiltration can also cause water vapor to condense inside walls and ceilings, causing insulation to become wet and ineffective and resulting in the growth of mildew and structural damage. While it is possible to make a home too air tight without proper ventilation, the vast majority of homes are much too drafty. The Energy Advisor has determined your home probably has excessive air infiltration and could benefit from professional air sealing services.

Blower door assisted air sealing is an effective and accurate method to measure air tightness and identify areas where air infiltration is occurring. Using the blower door, a contractor measures overall leakage and identifies specific locations. Those locations are then treated using a variety of methods (caulk, spray foam, weather stripping, etc.). Leakage is measured periodically during the process to ensure that the home is not sealed too tightly. Safety testing of any combustion appliances in your home should be conducted before and after any air sealing is done. This is the only method to accurately and safely perform air sealing on a home.



### Behavioral insights

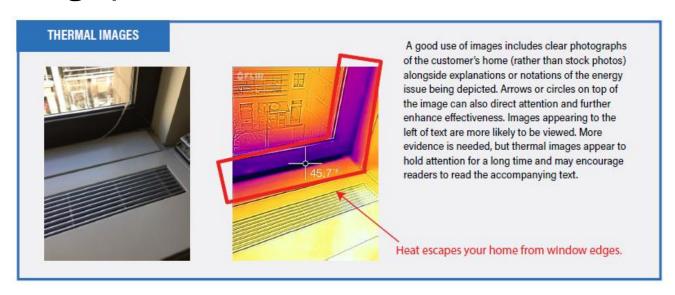


- Social comparison
- Benefits framing
- Barrier removal
- Vivid language



#### Design

- Consistent structure
- High-quality photos with explanations
- Tables and graphs





## Information placement

Key information in the front



Additional details in the back



## Assessment and presentation

Personally engaging and Accessible





## Six Key Recommendations

- 1. Personalization
- 2. Language
- 3. Behavioral insights
- 4. Design
- 5. Information placement
- 6. Assessment and presentation





# behavior, energy & climate change

November 17-20, 2019

SACRAMENTO, CA

Advancing behavioral research, policy and action to speed climate solutions

Hyatt Regency Sacramento
Pre-conference Workshops: November 17
beccconference.org







#### **Key Points**

- ACEEE conducted a study to determine how best to present information to homeowners following audits.
- Six key recommendation areas were identified: personalization, language, behavioral insights, design, information placement and assessment & presentation.
- Findings are detailed in a full report and fact sheet available at <a href="http://www.aceee.org/research-report/b1901">http://www.aceee.org/research-report/b1901</a>.







Brian Just
Vermont Energy Investment Corporation





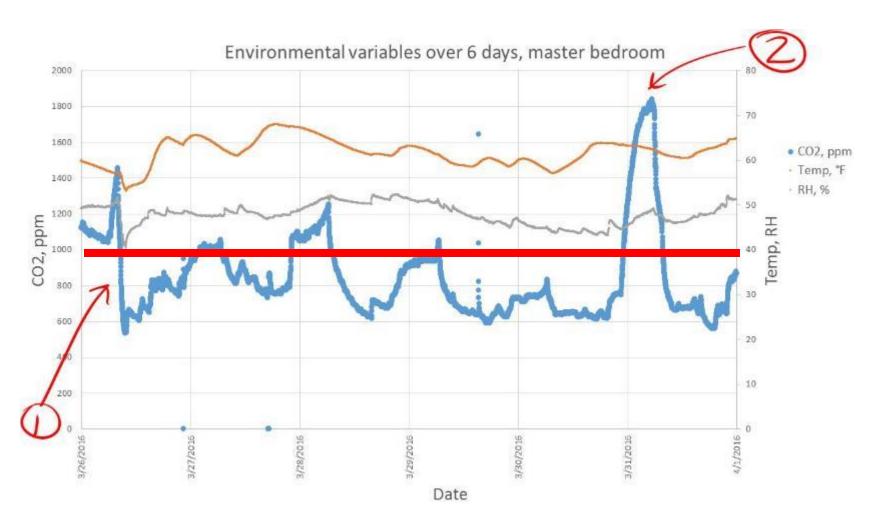
# Nighttime carbon dioxide (CO2) levels in bedrooms in 22 Vermont homes



#### Introduction



# Why I asked





# Why measure CO2?

- Other stuff is probably far worse...
  - VOCs (e.g. formaldehyde)
  - Particulates
  - Radon
  - The rest: CO, moisture, smells, etc.
- But CO2 is:
  - Easy and cheap to measure in real time
  - Reliably created in every (occupied) home
  - Probably a decent proxy for a lot of the other stuff



#### How much CO2 is too much?

- Codes target 1,000 ppm
- OSHA limit 5,000 ppm exposure limit (8-hr)\*
- At 40,000 ppm, immediately dangerous to life or health concentrations (IDLH)\*



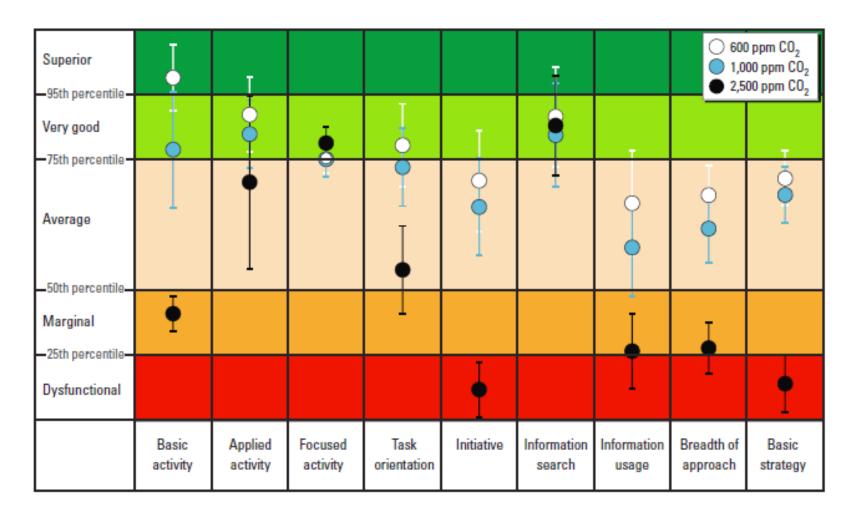
- 2016 Joe Allen / Harvard study\*
  - 24 office workers, 6 days
  - Variables: CO2 (600-1,400ppm), VOCs, outdoor air
  - Cognitive testing at 3pm each day
- Cognitive scores
  - 61% higher on "Green" days
  - 101% higher on "Green+" days
  - VOCs and CO2 mattered independently, especially in higher level functions



<sup>\*</sup>Allen JG, MacNaughton P, Satish U, Santanam S, Vallarino J, Spengler JD. 2016. Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments. Environ Health Perspect 124:805–812. DOI: 10.1289/ehp.1510037

- 2012 Satish / NIEHS study\*
  - 22 people
  - CO2 at 600, 1000, and 2500 ppm for 2.5 hrs
  - Cognitive testing





<sup>\*</sup>Satish U, Mendell MJ, Shekhar K, Hotchi T, Sullivan D, Streufert S, Fisk WJ. 2012. Is CO2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO2 Concentrations on Human Decision-Making Performance. Environ Health Perspect 120:1671–1677; DOI: 10.1289/ehp.1104789



- 2015 Denmark survey\*
  - 16 students in dormitories
  - CO2: 835ppm vs. 2,395ppm (avg)
- Results (with enhanced ventilation)
  - Higher perceived air quality
  - Sleep "efficiency" improved
  - Next-day sleepiness reduced
  - Grammatical reasoning improved



#### How much CO2 is too much?

- Codes target 1,000 ppm
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- At 40,000 ppm, immediately dangerous to life or health concentrations (IDLH)\*



#### **Protocol**



#### Two phases

- Phase I: Home inspection
  - Screening
  - Building age
  - Building sketch, including master bedroom volume
  - Air tightness test (blower door)
  - Ventilation system type and flow test
- Phase II: CO2 testing
  - 4 nights (door open/closed/open/closed)
  - Log to verify instructions and record irregular events



#### **Testing setup**

- No restrictions on building age, building type, air tightness, size, ventilation system type
- Heating season (windows closed)
- CO2 probe in primary occupied bedroom
  - Draft free location, approx. 3' above floor
  - Min. 3' from nearest sleeping being
  - Min. 1' free space between probe and nearest vertical surface



## **Testing equipment**

- TSI VelociCalc 9565-P meter with TSI 986 probe
  - CO2 range: 0-5,000 ppm
  - CO2 accuracy: ±3% of reading or 50 ppm,
    - whichever greater
- Frequency: 1/min





#### **Variables**

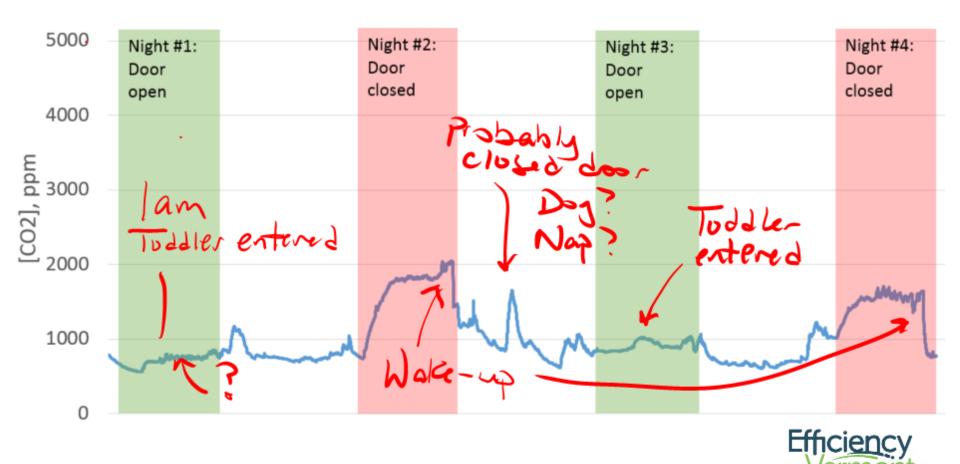
- Home age: 1890 to 2010s
- Home type: 19 SFD, 3 SFA
- Whole-home ACH50: approx. 1.5 to 10
- Occupancy: 1-3
- Bedroom volume: 900-2500 cf
- Heating: 10 forced air, 12 unforced air
- Ventilation: 20 EOV (7 auto controls), 2 HRV



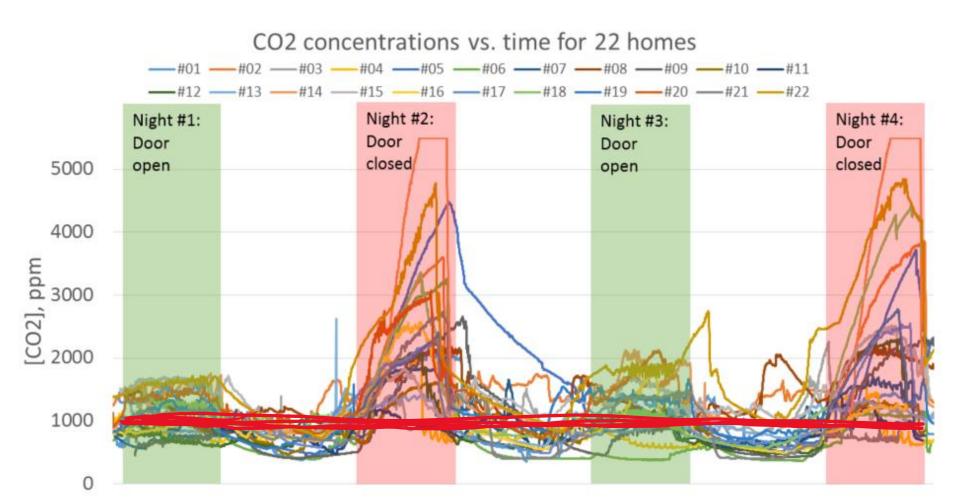
# Results



# A glance at one home...



# Data (all of it)





# Why?

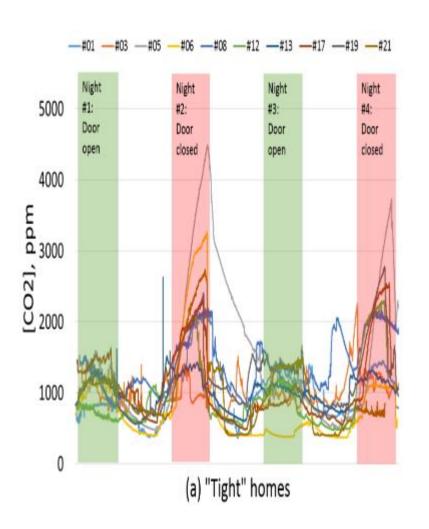


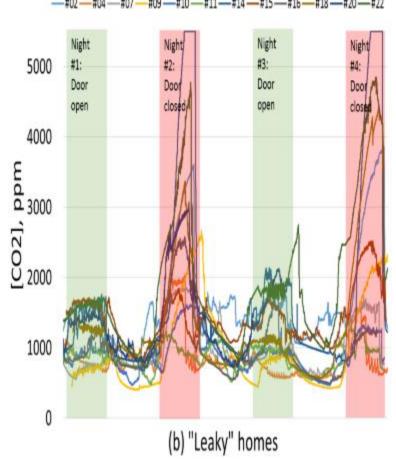
# **Theory #1: Airtightness**

This isn't as much of a problem in older / leakier homes



#### Tight homes\* (10) vs. leaky homes (12)





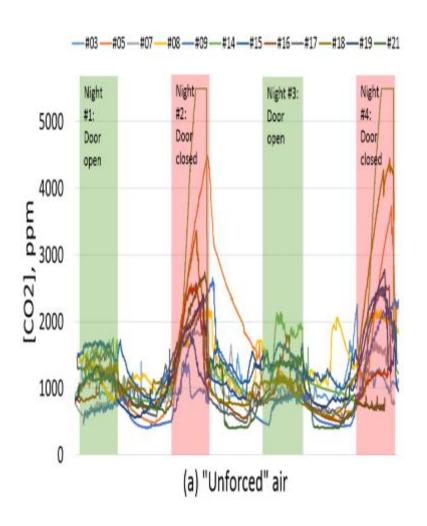


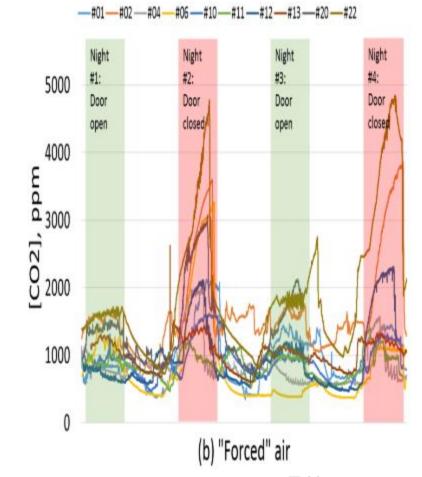
## Theory #2: Forced air

Mechanically moved air heat helps circulate, reduce CO2 levels



#### Unforced air (12) vs. forced air (10)







## **Theory #3: Occupant density**

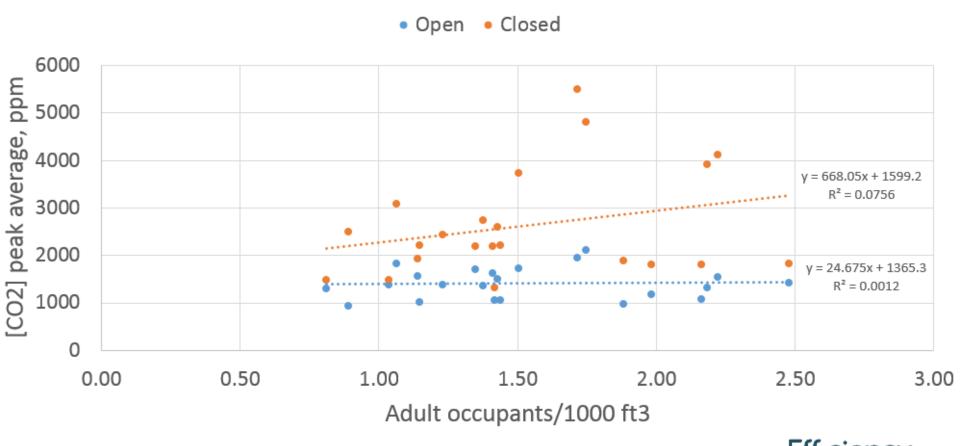
Peak CO2 levels is linked to number of occupants and bedroom volume

I.e. the more people/pets and the smaller the bedroom, the worse things will look



# Theory #3: Occupancy/volume

CO2 peaks compared to occupancy/bedroom volume, door state

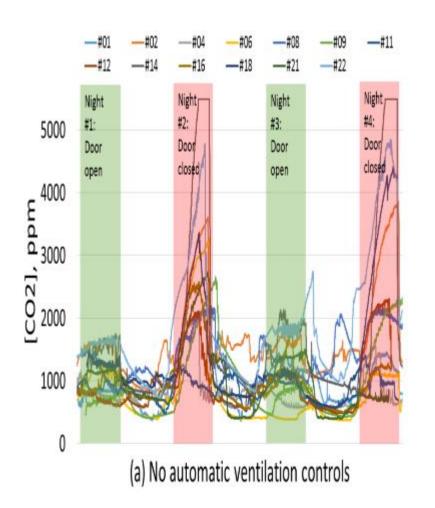


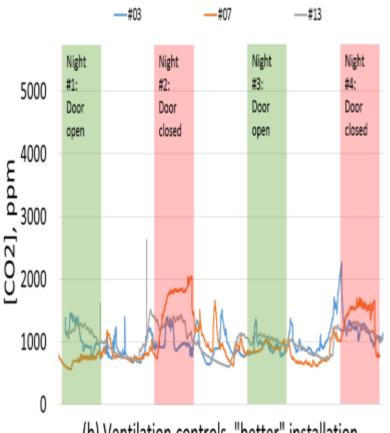
# **Theory #4: Balanced ventilation**

Intentional balanced ventilation helps (or at least exhaust ventilation with controls)



# No automatic ventilation controls\* (13) vs. "better" installation and controls\*\* (3)





(b) Ventilation controls, "better" installation

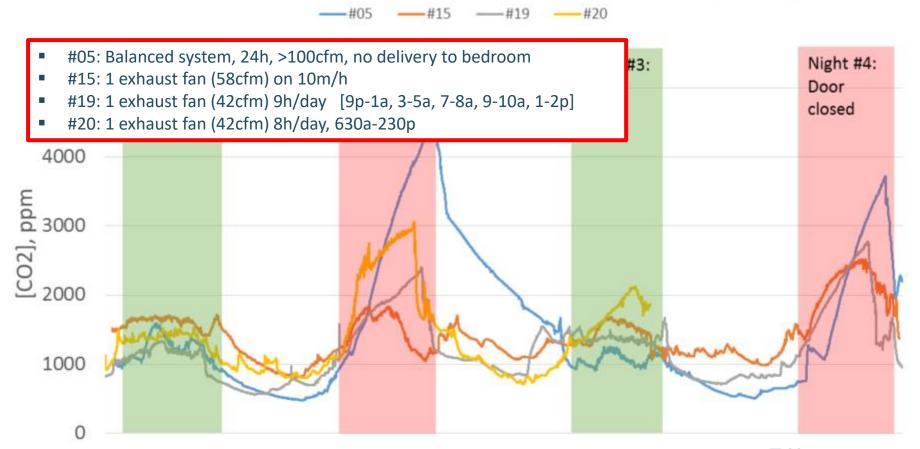
<sup>\*</sup> No ventilation or ventilation only on manual switches





# Homes with controls or balanced system but sub-par install (4)

CO2 concentrations vs. time, homes with ventilation controls (4 worst)

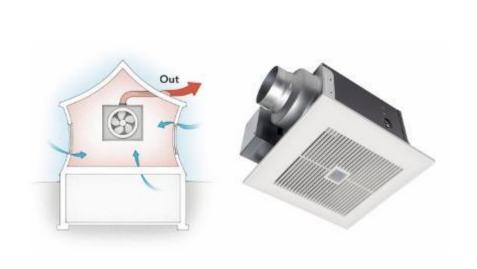


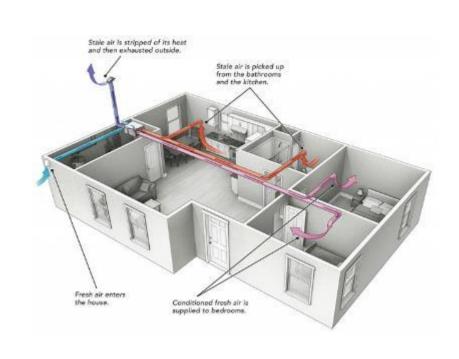


#### Discussion



# **Exhaust-only vs. balanced**



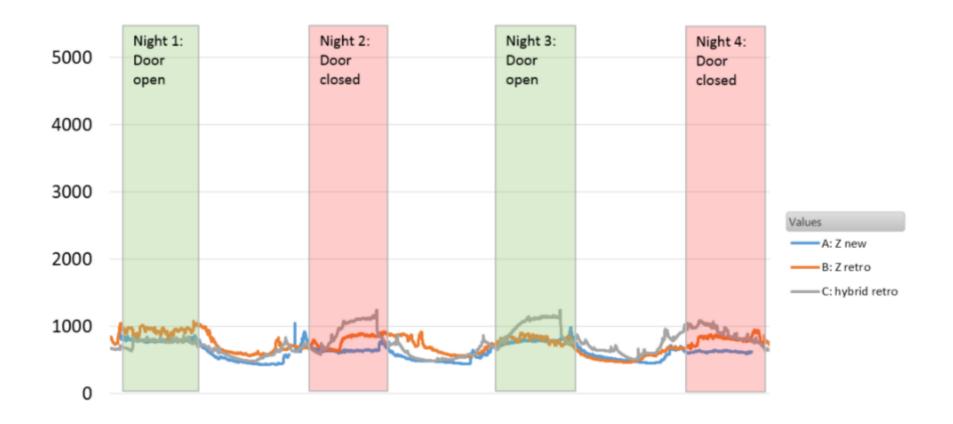


#### Think about bedrooms:

- Where does fresh air come from?
- Does the bath fan ensure fresh air gets to where you want it?

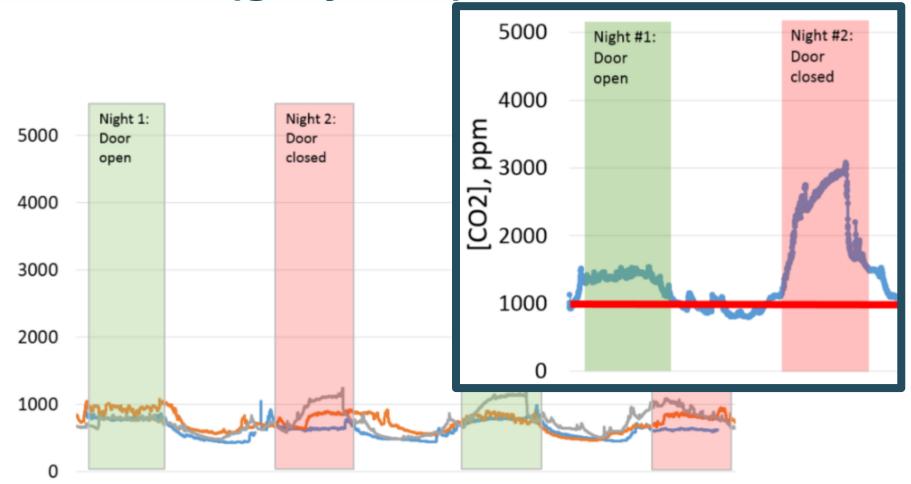


#### **Later: 3 homes with HRVs**



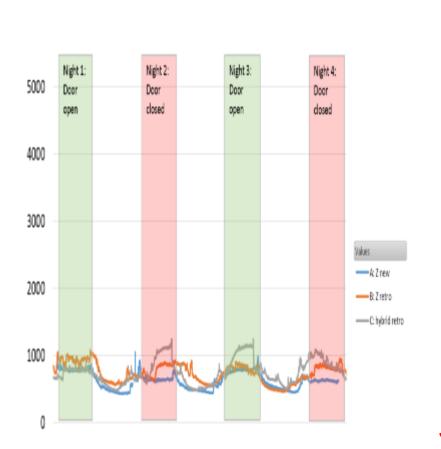


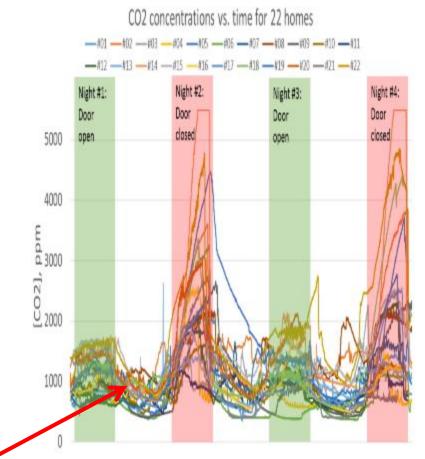
Home C (gray line) before retrofit





#### Vs. other 22 homes





Many of these homes aren't getting below 800-900 ppm, even after being unoccupied for 12+ hrs

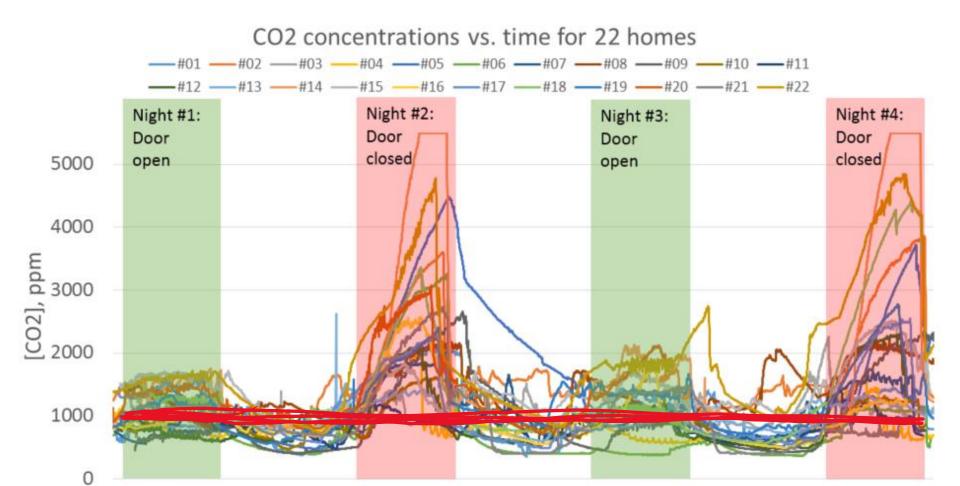


#### Summary

- A lot of homes may have substandard indoor air quality, as indicated by [CO2] > 1000 ppm
- Leaky homes and/or forced air systems do not assure better air quality
- Balanced ventilation works, but each bedroom needs a fresh air supply



#### Reminder





#### Full report available:

https://www.efficiencyvermont.com/news-blog/whitepapers/breathe-well-sleep-well-improving-ventilation-in-cold-climate-homes



bjust@veic.org



#### **Key Points**

- Many homes may have substandard air quality as measured by C02 levels.
- Leaky homes and/or forced air systems do not assure better air quality.
- Balanced ventilation works, but each bedroom needs a fresh air supply.





#### Register for the Better Buildings Summit



- **WHEN**: July 10-11, 2019
- WHO: Better Buildings partners & stakeholders, & ~200 speakers with proven solutions
- WHAT: 2 days of sessions, networking, & sharing the most successful energy efficiency strategies
- WHERE: Arlington, VA across from Washington D.C.
- INFO: energy.gov/betterbuildings/summit

It only happens once a year

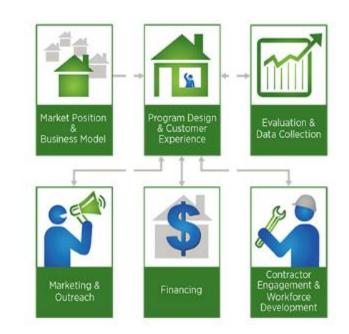




#### Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks explain why and how to implement specific stages of a program.
- Quick Answers provide answers and resources for common questions.
- Proven Practices posts include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! present resources on advanced technologies, HVAC & Heat Pump Water Heaters, including installation guidance, marketing strategies, & potential savings.



https://rpsc.energy.gov





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